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Stored Program Controlled Network:

CCIS and SPC Network Performance

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Common-channel interoffice signaling (CCIS) represents a major advance in interoffice signaling speed and capability over current inband signaling systems. The introduction of CCIS between Stored Program Control (SPC) switching offices is reducing ineffective machine attempts (IMAS) caused by transmission and switching irregularities associated with inband signaling. Because signaling between CCIS-equipped switching offices is concentrated in a relatively small number of signaling links and signal transfer points (STPS), a high standard of performance for the signaling network is essential. Therefore, the design of the signaling network incorporates many features to assure a high degree of availability. Cumulative data on STPS and studies of signaling links are the principal measures of signaling network performance. Data on their performance are presented that confirm the high availability of the signaling network.

I. INTRODUCTION

Common-channel interoffice signaling (CCIS) was introduced to provide the advantages of greater economy, faster call setup, improved security from fraud, and improved flexibility. The initial CCIS implementation was limited to class 1 to class 4 toll offices, but was extended to class 5 end offices during 1981. Several companion articles provide detailed accounts of CCIS implementation and describe its characteristics.

At year-end 1981, over 160 toll switching offices were interconnected through the CCIS network, which then comprised 24 signal transfer points (STPS) and signaling links serving over 400,000 trunks. The signaling link consists of an analog voice bandwidth channel with a CCIS terminal at each end. These links currently operate at a data rate of 2400 b/second. Because of the increasing traffic in the network, higher-speed links (4800 b/s) are being introduced.

Supervisory and address signaling information for a conventional call is usually transmitted directly from one switching system to the next over the same communication channel used for talking. A CCIS call, on the other hand, uses the separate, duplicated, signaling network to carry its supervisory and address signaling information. Since CCIS-equipped switching offices access the signaling network through a pair of STPs, signaling for a trunk between two CCIS switching offices will typically be routed through one or two STPs and two or three signaling links, depending on whether tbe two switching offices are served by the same or different STP pairs.

Clearly, the concentration of CCIS into a small number of signaling links and STPs greatly increases the consequences of a signaling failure. The original CCIS system design recognized the importance of signaling path availability and provided link and STP redundancy, tolerance to transmission errors, and automatic response to signaling network failures to assure that SPC network completion objectives were not jeopardized. This paper describes the differences between conventional signaling and CCIS methods, examines both signaling network performance and SPC network performance, and discusses the reduced rate of IMA observed with CCIS between modern stored program control systems.

II. INTEROFFICE SIGNALING

Interoffice signaling conveys the supervisory and address information necessary to switch calls through the telephone message network. Supervisory signals are used to initiate and release connections and to control charging. Address signals route the called number to its destination.

Conventional interoffice signaling separates the supervisory and address functions. Supervisory signaling equipment is usually dedicated to each trunk, while address signaling equipment is shared in a common pool. Address signals are sent by either dial pulsing (DP) or multifrequency (MF) pulsing.

The CCIS network interconnects switching office processors. Interoffice signaling messages transmit supervisory and address information. This information is checked and errors are corrected by retransmission before they are accepted by the switching office.

III. THE SIGNALING NETWORK

3.1 Configuration and response to failure

The basic configuration of the signaling network for CCIS is shown in Fig. 1. Much of the inherent availability of the signaling network is a result of the architecture of this arrangement.[1,2] Switching offices in each signaling region have access to the signaling network through

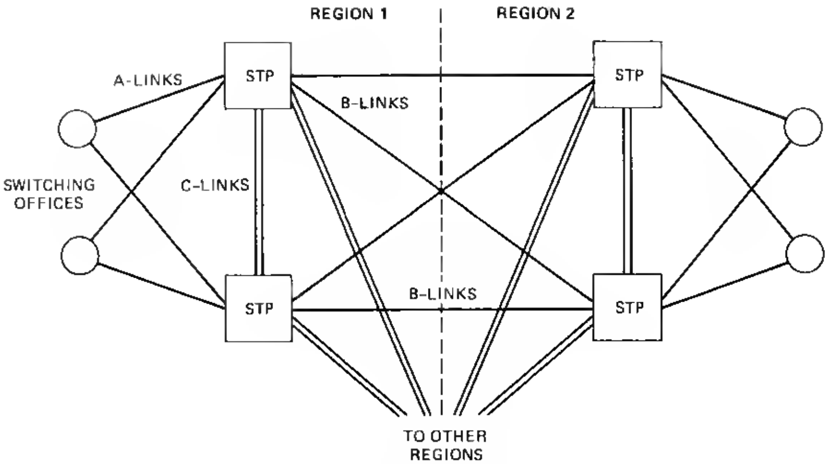

Fig. 1—The CCIS network.

access links (A-links). These links provide access to regional STPs. Switching offices may also be connected to other than home STP, and these access links are designated E-links. The STPs route signaling units to outgoing links based on address information contained in incoming signal units. For intraregional signaling, the outgoing link would be another A-link. For interregional signaling, messages are routed onto bridge links (B-links) that provide access to STPs in another region.

The signaling regions with a heavy volume of traffic are supplemented by area STPs. Switching offices access area STPs by A-links and E-links. Area STPs are connected to regional STPs by D-links and to area STPs by B-links.

This network is fully duplicated. Regional and area STPs are provided in pairs, and A-links or E-links from an office are duplicated with mates terminating at each STP of the pair. The B-links and D-links are duplicated from each STP to form a quad. Under normal conditions, traffic loads are balanced among the links and STP pairs. However, the loads are engineered so that in the event of a failure, the mate link or the mate STP can carry the full traffic load. The links connecting mate STPs (C-links) carry traffic only under certain transient failure conditions and are provided, after the first pair, in proportion to the number of A-links and E-links in a region.

The redundancies are provided so that alternate signaling paths are available in the event of link or STP failures in the network. One assumption that is implicit with redundant arrangements is that failures of mate pairs are independent. Physical diversity is one way of assuring independence. Diversity is achieved with STPs by locating

them in different cities. To the greatest extent possible, mate signaling links use separate transmission circuit facilities for their entire length.

Effective use of redundancies means that the signaling network must respond quickly and automatically to failures and reestablish signaling paths with little or no interruption to the signaling traffic. Two general classes of failures are expected. First, the links may experience hits or fades characterized by high error rates for short periods of time. Second, major facility outages or hard equipment failures may occur which could last for several minutes or longer. The CCIS network is designed to handle these situations with minimal deterioration of signaling performance.

The CCIS terminals at each end of a signaling link continuously monitor errors by decoding an 8-bit check code appended to each signaling unit. This code is designed to detect single errors and a large class of multiple errors and error bursts. In addition, the terminal can automatically detect loss of carrier or synchronization, while an improper sequence of signaling units is detected by the switching office processor through the use of reasonableness check tables.

Under normal circumstances, errors are corrected by retransmission. However, if a high error rate is detected for a relatively long period of time, about one-third of a second or longer, the terminal assumes that the link is faulty and initiates recovery action. Link recovery procedures can be illustrated by considering A-links. When the error threshold is exceeded, the terminal will alert its host processor to direct traffic to the mate link. Changeover signaling units are then sent to the far-end terminal to coordinate the changeover in case the problem affected signaling in one direction only. The STP temporarily routes traffic destined for the switching office over the C-link to the mate STP to avoid the failed A-link.

Terminals at both ends of the A-link then attempt to restore service. In the case of A-links, an extra level of redundance is provided through use of two voice frequency links (VFLS) per signaling link. When resynchronization is achieved on one of the VFLS, the terminals monitor the error rate for 15 seconds to prove in the link. If the error threshold is not exceeded, the link is restored to service and the normal routing of traffic is resumed.

If recovery cannot be effected within 3 minutes, the terminal is taken out of service. This is accompanied by alarm indications at the switching office and STP and automatic initiation of terminal diagnostic routines. The STP sends special control messages to other STPs in the network to route all traffic destined for the failed link directly to the mate STP and its A-link. This procedure avoids the use of C-links, except for short interruptions. It also minimizes total delay in signaling through the network when failures do occur.

Similar network reconfigurations are automatically invoked when an STP fails. In the event of an STP outage, the CCIS terminal for each signaling link detects the outage and autonomously signals this condition to the far-end terminal. Traffic destined for the A-links is automatically rerouted by the switching office to the mate STP, and distant STPs also reroute B-link traffic to the mate.

It can be seen from this brief discussion that the simultaneous occurrence of several unlikely events is required to isolate a switching office from the signaling network. One possibility is A-link pair failures. Other possibilities include B-link quad failures, an A-link plus a B-link pair plus all regional C-links, or an STP regional pair outage. The combined effect of all these possibilities is the unavailability of the network. By using actual field failure statistics, it can be shown that the probability of switching office isolation is very small, as will be discussed below.

3.2 Signaling network performance monitoring

All switching offices and STPs in the CCIS network have provisions for monitoring and reporting CCIS traffic and signaling link performance. Traffic and performance data are continuously gathered at the STPs by specialized minicomputer systems called peripheral bus computer (PBCs).[3]

Reports generated by the PBC are used mainly by the STP management and craft to assess traffic loads and link occupancy, to aid in maintenance activity, and to index the overall performance of the STP and signaling links. Many impending problems, characterized, for example, by high error rates or an unusual number of changeovers can be spotted and corrected by the craft before signaling performance is affected.

Data on signaling link performance have not been collected continuously for all links. The sheer mass of information involved would be unmanageable. However, each node monitors link performance to generate exception reports to guide ongoing maintenance activity. Occasionally, Bell Laboratories conducts special studies to assess link performance by examining data from a sample of links. Very little variation in the average characteristics of links has been observed in these studies.

3.3 Reliability of STPs and signaling links

The probability that a switching office will be isolated from the signaling network is equivalent to the probability of certain multiple failures in the network, as mentioned above. The probability of service-affecting multiple failures is, in turn, a function of the reliability of the STPs and the signaling links. However, it is important to recognize that

certain network failures would be more serious in their effect than others. For example, the simultaneous outage of a regional STP pair would take almost all CCIS trunks in the region out of service. (Some high-traffic trunk groups are homed on distant regional STPs for increased efficiency.) On the other hand, an A-link pair failure would take out of service only the trunks assigned to that pair (up to 2250 or 4500 trunks, depending on link speed). As will be shown, the probability of the former failure is orders of magnitude lower than the latter, although both probabilities are small.

The reliability of STPs and signaling links can be expressed in terms of their mean-time-to-failure (MTTF) and mean-time-to-repair (MTTR). In the case of STPs, these parameters can be estimated from outage records. From mid-1976, when the first STPs were cut to service, through 1980, 86 system years of STP service have been accumulated. There have been 14 outages and an accumulated downtime of 590 minutes. These numbers translate to an MTTF of 6.1 years and an MTTR (the average downtime per outage) of 42 minutes. Assuming that STP outages are independent, the probability of simultaneous regional outages can be computed. The probability can be expressed as a mean-time-to-pair-failure (MTTPF) or as an average downtime, D, in an interval of time T. From well-known results of availability theory:

$$\text{MTTPF} = \frac{\mu + 2\lambda}{2\lambda^2}$$

and

$$D = T\left(\frac{\lambda}{\lambda + \mu}\right)^2,$$

where λ and μ are the reciprocals of MTTF and MTTR, respectively, expressed in the appropriate units. Thus, for regional STP pairs, the estimated MTTPF is over 200,000 years and the estimated D is about 5 ms per year. In other words, the probability of a regional STP pair outage is negligibly small and has never yet occurred.

Estimates of MTTF and MTTR for signaling links have been generated from sample studies using PBC data available at STPs. In one representative study conducted in 1980, about 200,000 A-link hours of activity were monitored at ten STPs. For each link, changeover peg counts and out-of-service time were measured on a daily basis. The study showed that link failures are predominately caused by short hits or fades on the VFL. The mean out-of-service time was found to be 1.6 minutes. The mean time between changeovers was found to be about 17 hours. Taking these numbers to be the MTTR and MTTF, respectively, for an A-link, the MTTPF is estimated to be 0.6 year, while the downtime is estimated to be 1.3 minutes per year. Given this probability for pair

failure, the expectation for pair failures in the study data was 0.5 link hour. The observed incidence of unambiguous pair failures (those not related to switching office outages or interrupts) was 0.3 link hour. The agreement is good and indicates that the A-links do indeed behave as a redundant system.

IV. THE SPC NETWORK

The CCIS network performance just described has an increasing impact on the service provided by the SPC network as CCIS deployment expands. The volume and quality of service delivered by the SPC network is measured through a variety of traffic and switching equipment measurements. Their purpose is to provide sufficient information to monitor the rate of successful call completions and to help detect areas where maintenance activity is required.

Recent call completion studies indicate 69 percent of direct distance dialing (DDD) attempts are successfully completed. Major causes of unsuccessful attempts are busy or no-answer conditions encountered at the called customer's phone. These conditions represent 25 percent of DDD attempts. The remaining unsuccessful attempts (6 percent of DDD attempts) are considered to be ineffective attempts (IAS) caused by either the calling customer or the message network. The IAS are comprised of three subcategories that include ineffective traffic attempts (ITAS), ineffective network attempts (INAS), and IMAS. An example of an ITA is an 800 Service call that is blocked because it originates outside the band specified by the customer. An example of an INA is a call that is abandoned by the originator before it reaches the talking state. However, the principal IA component used to measure SPC network performance is the IMA which is described next.

4.1 Ineffective machine attempts

An IMA is defined at a given switching office as an incoming bid for service which is recognized by the switching office but which does not result in a completed call, a busy, or a no answer, as experienced by the customer. An IMA may result from a switching office or interoffice signaling malfunction, a lack of sufficient trunks or other switching resources, or a customer or operator dialing irregularity. The IMAS are classified into several broad categories as shown in Table I.

A summary of the IMA failure rate for each category, expressed as a percentage of total incoming attempts, less false starts, provides a uniform set of switching office performance measurements that are useful in directing management's attention and effort toward items requiring service improvement. The NC category reflects primarily the adequacy of outgoing trunk provisioning, although it is influenced by overload and network management controls and transmission facility

and switching equipment failures. Vacant codes are caused by dialing errors, erroneous or missing translation data at a switching office, or the loss of one or more digits by interoffice signaling. The RO category best reflects the quality of service provided by the toll switching, interoffice signaling, and transmission equipment, since it is relatively insensitive to dialing mistakes which are usually detected by the originating class 5 office. The switching system connects calls failing in this manner to a reorder tone or announcement.

4.1.1 Incoming reorder IMA

Incoming reorders are detected during digit analysis of the received address by the toll switching office and usually result from reception of fewer than the expected number of digits. Typically, interoffice signaling failures resulting from MF pulsing and CCIS are classified as shown in Table II. The DP failures are classified similarly to MF. Certain CCIS irregularities, such as reception of two conflicting initial address messages (IAMS) for the same trunk or an IAM identifying an unequipped trunk, are rejected by sending back a confusion (COF) or unequipped label (UQL) signal, and the call is either reattempted or treated as an outgoing IMA by the preceding office.

Toll offices equipped for centralized automatic message accounting (CAMA) include unique CAMA failures in the incoming reorder IMA. A

Table I—Ineffective machine attempts

IMA Type	Definition
Reorder (RO)	
Incoming	Failure to receive all address digits or to receive notification of successful CCIS continuity check.
Connecting	Switching office fault or insufficient resources.
Outgoing	Failure of interoffice integrity check or signaling.
Vacant code (VC)	Unassigned called number.
No circuit (NC)	All trunks busy to destination.

Table II—Incoming reorder IMA

Conventional RO	Definition
Permanent signal time-out—PST	No key pulse (KP) signal or address digits received.
Partial dial time-out—PDT	Received at least the KP signal, but not the start (ST) or an incomplete set of DP digits.
Pulsing error—PER	Received other than the expected number of digits, or an erroneous or invalid digit.
CCIS RO	**Definition**
Incomplete address detected—IAD	Received other than the expected number of digits.
Continuity time-out—CTO	Failed to receive the continuity (COT) signal after the IAM.

CAMA office provides billing information for customer-dialed DDD calls from class 5 end offices not equipped with the AMA function. Customers from step-by-step end offices are connected to the CAMA office, after dialing the DDD access digit (1) and then dialing directly into the CAMA office. These dial-pulsing, immediate seizure (DP-IS) trunks can be expected to have a higher reorder rate than MF trunks since the screening that is normally done at the class 5 office is now performed at the CAMA office. The CAMA office must also obtain the calling number identity from the end office, and if automatic number identification (ANI) is not available, a CAMA operator must be connected to obtain the customer's telephone number. Failure to connect an operator or to obtain the calling number are also counted as incoming reorders.

4.1.2 Connecting reorder IMA

Connecting reorders include those failures which are directly attributable to the switching office, either because of an equipment fault or unavailability of a traffic-sensitive resource, such as a call register, network path, or CCIS continuity-check transceiver.

4.1.3 Outgoing reorder IMA

Outgoing reorders result from failure of the interoffice verification checks or from detection of signaling abnormalities associated with the transfer of address digits to the next office. Detection of any of these problems during the first attempt, except for the CCIS address complete (ADC) time-out, results in a reattempt to complete the call on another outgoing trunk. If the reattempt also experiences any of the outgoing problems, the call is then routed to reorder. Table III summarizes the outgoing failure categories.

4.2 Stored Program Controlled Network performance studies

To determine how CCIS compared with conventional signaling performance, separate studies of call failure rates were performed in selected No. 4A ETS and most No. 4 ESS systems. The data from six 4A ETS systems with over 94 million incoming attempts were collected during June 1980. Forty No. 4 ESS systems with over 1.5 billion incoming attempts were studied during January 1981.

The signaling mix of the six No. 4A ETS and the 40 No. 4 ESS systems was virtually identical: 6 percent of the attempts were dial pulse, 64 percent MF, and 30 percent CCIS. A summary showing a comparison of conventional and CCIS reorder, NC, and VC rates is provided in Table IV. The detailed results of these studies are tabulated in Tables V, VI, and VII for incoming, connecting, and outgoing reorder rates.

Table III—Outgoing reorder IMA

Conventional RO	Definition
Integrity check failure—IKF	Failed to receive off-hook in response to seizure of delay-dial trunk.
No-start dial—NSD	Delay-dial signal not removed or wink signal not received.
Unexpected stop—UXS	Received unexpected stop (off-hook) during outpulsing.
Glare—GLR	Steady wink or delay-dial received after outgoing selection of two-way trunk (detected as NSD in No. 4A ETS*).
Expected stop time-out—XST	Expected stop received during DP outpulsing was not removed.
CCIS RO	**Definition**
Continuity check failure—CKF	Failure of interoffice continuity check of outgoing trunk.
Call failure detected—CFD	Received a BLK†, CDF, UQL, or RST‡ signal after outgoing trunk selection.
Address complete time-out—ADC	Failed to receive the ADC signal after sending the COT signal.
Signaling network failure—SNF	Received an MRF§ or UQL signal or no signaling path was available after outgoing trunk selection.
Glare—GLR	Received an IAM at noncontrol office after outgoing selection of a two-way trunk.

* ETS—Electronic translator system.
† BLK (blocking)—Request the far-end office to remove a trunk from service.
‡ RST (reset trunk)—Return the trunk to the idle state.
§ MRF (message refusal)—Signaling network could not locate a signaling path.

Table IV—Study results—failure rates in per cent

System/Signaling Type	Reorder Incoming	Reorder Connecting	Reorder Outgoing	Reorder Total	VC	NC	Total IMA
No. 4A ETS					0.725	0.334	
DP plus MF/EM	0.482 (MF = 0.356)	0.017	0.061	0.560			1.619
CCIS	0.006	0.067	0.021	0.094			1.153
No. 4 ESS					0.621	0.228	
DP plus MF/EM	0.612 (MF = 0.334)	0.001	0.046	0.659			1.508
CCIS	0.029	0.001	0.021	0.051			0.900

4.3 Discussion of results

4.3.1 General

A review of the study results in Table IV indicated that the reorder rate for CCIS attempts is substantially less than for traffic using conventional signaling. Consequently, it is clear that CCIS has not jeopardized network completions, but appears to have reduced the IMA caused by switching and transmission irregularities.

Several other observations are also apparent. One is that the No. 4 ESS and No. 4A ETS results are generally consistent, except for the connecting reorder and the CCIS incoming reorder categories. Both of these discrepancies will be discussed in detail later in this article. Some

of the other differences in results are caused by minor differences in some time-out intervals used in the two systems and a more extensive capability in No. 4 ESS to detect certain irregularities. As examples, No. 4A ETS systems generally do not count conventional signaling irregularities if the customer hangs up prior to being connected to an announcement, but the No. 4 ESS does. Also, the No. 4 ESS usually checks that the correct number of digits has been received to route a call to its ultimate destination; whereas, the No. 4A ETS often limits its check to the number of digits required to be translated for outgoing trunk selection, typically three or six digits.

The study results do not permit a true comparison of CCIS and conventional signaling because of differences in the trunking base for each type of signaling. The CCIS data are confined to CCIS intertoll trunks interconnecting No. 4 ESS, No. 4A ETS, and No. 1/1A ESS switching systems, while the MF and DP data include the remaining intertoll trunks and all toll-connecting trunks. Nonetheless, the study results demonstrate the performance of CCIS in a pure intertoll trunk environment.

4.3.2 Incoming reorder

The conventional signaling incoming reorder data shown in Table V for the study offices were heavily influenced by the presence of DP trunking. Although DP trunks initiated only 6 percent of the conventional signaling attempts, they were involved in 26 percent of the No. 4A ETS incoming reorders and 43 percent of the No. 4 ESS incoming reorders. One factor contributing to the DP error rate is CAMA traffic originating from step-by-step end offices. Customers from these offices dial DDD calls directly into the toll office after dialing the "1" access digit. The toll office is now subject to the same dialing irregularities

Table V—Incoming reorder data (percent)

Conventional Signaling				
	No. 4A ETS		No. 4 ESS	
Reorders	MF + DP	MF	MF + DP	MF
Permanent signal time-out	0.281	0.218	0.325	0.209
Partial dial time-out	0.118	0.057	0.119	0.020
Pulsing error	0.074	0.081	0.111	0.105
Miscellaneous	0.009	—	0.057	—
	0.482	0.356	0.612	0.334
CCIS				
Reorders	No. 4A ETS		No. 4 ESS	
Incomplete address detected	0.005		0.026	
Continuity signal time-out	0.001		0.003	
	0.006		0.029	

normally experienced by the class 5 end office. The CAMA toll offices are also sensitive to subscriber loop irregularities, which can appear to the step-by-step office as the DDD access digit 1 and result in false seizures and permanent signal or partial dial time-outs at the toll office. The other significant source of DP traffic originates from class 4 step-by-step toll offices whose performance and maintainability do not match the more modern electromechanical common control and electronic switching systems. In view of the special nature and limited amount of DP traffic, it is appropriate to concentrate further discussion on the relative performance of CCIS and conventional signaling using MF pulsing.

Common-channel interoffice signaling shows an order of magnitude improvement over conventional signaling using MF pulsing with an incoming reorder rate measured at 0.029 percent for No. 4 ESS and 0.006 percent for No. 4A ETS. The CCIS reorder is almost entirely due to the IAD component. An explanation for the improved CCIS reorder performance is offered in the following discussion. Furthermore, a sampling of the CCIS IAD reorders indicates that the address digits for these attempts were incorrectly received from the conventional signaling source by the first CCIS toll office.

The MF incoming reorder data from Table V indicates that 75 percent of such IMAS are permanent signal or partial dial time-outs. Common-channel interoffice signaling eliminates the possibility of similar failures by combining the incoming trunk seizure signal and the called-number address digits in the IAM, which will be retransmitted if an STP or the incoming office detects an error during reception of the IAM. The remaining MF incoming reorders are pulsing errors which include reception of an erroneous, invalid, or an incorrect number of digits. The CCIS error checking and retransmission effectively eliminate the erroneous digit as a problem, while the reception of an invalid digit or other IAM format irregularity causes the incoming office to return a COF signal, which requests the outgoing office to reattempt as described in Section 4.1.1. This leaves reception of an incorrect number of digits, designated as incomplete address detected (IAD) by CCIS and pulsing error (PER) by MF, as the only incoming IMA common to both MF and CCIS.

Conventional signaling is susceptible to loss or mutilation of part or all of the address digit stream because of undetected outpulser and receiver faults and transmission system hits, fades, and noise. Such is not the case with CCIS. To determine the cause of CCIS IAD reorder, a total of 216 outgoing CCIS attempts, which were rejected by a subsequent switching office because of an incomplete address, were monitored at the Norway, Illinois and Toledo, Ohio No. 4A ETS switching offices using the procedures to be described in Section 4.3.3. Over 75

percent of the failures were DDD attempts of the form NPA+NXX+$XXXX$ ($N = 2 - 9$, $X = 0 - 9$) and were received at the No. 4A ETS with other than the required ten digits. Because of its address screening limitations, the No. 4A ETS routed these attempts over CCIS trunks, usually with the NPA digits deleted, to the next office where they were correctly blocked as IAD. Invariably, the far-end office detecting the IAD was a No. 1 ESS or No. 4 ESS, except when eight digits had been received by the Norway or Toledo office. The apparent inability of a destination No. 4A ETS to detect these IADs occurs because it translates a received six- or eight-digit sequence of the form NXX+$XXXX$ in a dedicated area (NPA) code table and, thus, blocks the attempt as a vacant code instead of an IAD. The remaining failures were a mix of alternate routed INWATS and operator-originated attempts that also arrived at the Norway or Toledo office as an invalid digit sequence. A total of four attempts arrived with the correct number of digits. Two of these were of the form NPA+11XXX and were incorrectly blocked at the destination office because translation data specified a six-digit instead of a five-digit translation for the 11X code.

The higher CCIS reorder rate experienced by the No. 4 ESS during the study results from its superior incomplete address screening capability and the misclassification by No. 4A ETS of certain incomplete address sequences as vacant code instead of IAD. The No. 4 ESS is able to store an acceptable digit count (ADC) value in the routing data block which specifies the characteristics and available trunk subgroups of the selected outgoing route. The ADC specifies the number of digits required to be received from the preceding office if the call is to successfully complete to the selected outgoing route. If only one ADC value is specified, as in the case of a toll completing route to a class 5 end office, the screening is totally effective. However, in the case of an intertoll route selected by a three-digit translation, several ADC values must be specified to accept valid digit sequences such as NPA+1X1, NPA+11XXX, NPA+0/1XX+XXX, and NPA+NXX+$XXXX$. Consequently, address screening effectiveness is compromised, unless six-digit translation is specified to create routing data blocks for each of the ADC values or combinations.

The No. 4A ETS, because of its memory constraints, employs much simpler checks which are generally effective for only the first seven digits. The first three received digits are translated in either an area (NPA) or office code table, depending on the total number of received digits. Three-digit codes of the form 0/1XX are always translated in the office code domain. Thus, when the first digit is N (2-9) and the received digit count is 3, 4, 5, or 7, the attempt is translated in the office code table; otherwise, if the received digit count is 6, 8, 9, 10, or 11, the attempt is translated in the area code table. Unless the three-

digit code is in dual use as both an NPA and office code, it will appear only in the appropriate table. Consequently, an office code sequence containing 6 or 8 to 11 digits is blocked as a vacant code, as are area code sequences containing 3 to 5 or 7 digits. The IAD classification applies only to digit sequences containing insufficient digits for the specified 3-, 4-, 5-, or 6-digit translation and office code sequences containing four or five digits.

Most of the other differences between the MF and CCIS incoming reorder rates occur because the IMA failure rate for conventional incoming attempts tends to be overstated, since it includes an unknown number of noncall-related failures. This inaccuracy results primarily from the PST incoming reorder component of IMA, since the toll office cannot distinguish between a PST time-out caused by a false trunk seizure and an outpulsing failure at the preceding office. As mentioned previously, analog carrier failures are a primary source of false noncall-related PST failures on SF-equipped trunks. Generally, the PDT and PER components of incoming reorder IMA are considered to be call-related failures resulting from signaling or switching faults. However, the PER component may include an unknown number of attempts which arrived from the class 5 end office without being screened for the correct number of digits.

4.3.3 CCIS backward failure signals

Common-channel interoffice signaling includes a set of backward signals which allows a subsequent switching office to report call setup failures back to the originating office so that it may connect the attempt to the proper tone or announcement. Another use of these signals is to alert the originating and intermediate offices to certain IMA so they may record pertinent call data in an analysis file. These data include the received-address digits and incoming- and outgoing-trunk identities associated with an attempt receiving an address incomplete (ADI) or vacant national number (VNN) signal. This process is useful in identifying incorrect translation data or conventional signaling irregularities which cause such IMAs and it was used to collect the sample IAD IMA data at the Norway and Toledo offices.

Other backward signals provide notification of attempts blocked by NC, switching congestion, and switching equipment failures. These signals may optionally be recorded to determine the source of these blockages.

4.3.4 Connecting reorder

Table VI shows connecting reorder results for both conventional signaling and CCIS. The No. 4 ESS data show almost no connecting reorder for either conventional signaling or CCIS. This is due largely to

Table VI—Connecting reorder data (percent)

Conventional Signaling		
Reorders	No. 4A ETS	No. 4 ESS
Switching equipment failure	0.013	0
No network path	0.004	0
Queue time-outs	—	0.001
	0.017	0.001
CCIS		
Reorders	No. 4A ETS	No. 4 ESS
Switching equipment failure	0.033	0
No network path	0.004	0
No call register/no outpulser	0.030	0
No transceiver, etc.	0	0.001
	0.067	0.001

the superior reliability of the No. 4 ESS hardware over the No. 4A ETS electromechanical circuits and the fact that No. 4 ESS has an essentially nonblocking network.

4.3.5 Outgoing reorder

Table VII shows outgoing reorder study results. Outgoing reorder is roughly an order of magnitude lower than incoming reorder for conventional signaling, and no disproportionate contribution was noted for DP signaling. The primary reason is that outgoing attempts encountering a failure are permitted a single reattempt. The No. 4A ETS data show a conventional signaling first attempt outgoing failure rate of 0.299 percent, or roughly the same order of magnitude as incoming attempts that fail at 0.356 percent. However, the second outgoing trial results in a final failure rate of only 0.061 percent, confirming that 80 percent of the second attempts did not experience an outgoing failure. This does not necessarily imply that all reattempts were successful since the reattempt may have encountered NC or may have been abandoned. Other factors are that most of the defensive checks in both No. 4A ETS and No. 4 ESS are on the incoming side; outpulsing failures may only be detected as incoming failures in the next office and that outgoing reorder is "controllable" in the sense that an outgoing office can identify and remove a suspect outgoing trunk or outpulser from service, until it is repaired more easily than the incoming office.

The CCIS outgoing reorder rate shows a relatively modest improvement over conventional signaling in No. 4A ETS. In No. 4 ESS, an improved CCIS glare treatment strategy allowed a similar modest improvement of CCIS over conventional signaling. The principal reason only small improvements were seen is that both conventional signaling and CCIS systems reattempt calls that fail. As mentioned earlier, the second attempt dramatically lowers the call failure rates for both signaling types, leaving CCIS less room for improvement.

Table VII—Outgoing reorder data (percent)

Conventional Signaling		
Reorders	No. 4A ETS	No. 4 ESS
Integrity check failure	N/A	0.014
No-start dial	N/A	0.020
Unexpected stop	N/A	0.004
Glare*	—	0.006
Expected stop time-out and other	N/A	0.002
	0.061**	0.046
CCIS		
Reorders	No. 4A ETS	No. 4 ESS
Continuity check failure	0.012	0.004
Call failure detected	0.006	0.002
Address complete time-out	0.002	0.006
Signaling network failure	0	0.003
Glare	0.001	0.006
	0.021	0.021

* No. 4A ETS does not detect glare on two-way trunks, but classified this problem as no-start dial.

** Outgoing second-attempt failure detail is not available for the No. 4A ETS; however, total conventional outgoing reorder is provided.

4.3.6 Glare

Heavy calling rates on two-way trunk subgroups will normally result in some level rate of glare on second trials. Common-channel interoffice signaling takes three to five times longer to accomplish a seizure than conventional signaling because of the need to transmit IAMs through the signaling network. Consequently, CCIS has a longer unguarded interval and is more susceptible to glare. (Despite this longer unguarded interval, CCIS still provides faster end-to-end address signal transmission than conventional signaling.) Trunk hunting and reattempt strategies mitigate the impact of this difference. The higher CCIS glare rate originally observed for No. 4 ESS was strongly affected by results from one study office.[4] After the original study data were collected, the No. 4 ESS retrial strategy was changed so calls encountering glare were retried in a different trunk subgroup. This strategy was based on the assumption that the second trial would be performed in a trunk subgroup that was more idle than the first, reducing the chances of encountering glare on the second trial. The new strategy reduced glare reorder from 1500 to only 100 occurrences per day in the No. 4 ESS most strongly affected during the original study, and the results presented in this article confirm that the modified strategy has been completely effective in reducing the rate of CCIS glare to a rate equivalent to conventional glare.

4.3.7 Common-channel interoffice signaling stable-call reset

The CCIS switching offices disconnect some small percentage of calls by means of CCIS RST signals because of certain internal switching

problems or time-outs. Calls disconnected by RST signals are counted as CCIS stable-call resets in automatic system performance measurements. Stable-call resets should be included when comparing CCIS with conventional signaling, despite the fact that many stable-call resets are not signaling problems, but switching office problems.

Examples of some of the causes of stable-call resets include:

(*i*) Switching office equipment failures in which transient calls and stable calls are cleared in the process of initializing system memory associated with failed trunks.

(*ii*) Situations detected by audits in which a switching office detects two CCIS trunks connected, but with inconsistent trunk states.

Unfortunately, the stable-call reset count does not give a very precise indication of CCIS performance because nonsignaling components dominate the count. Also, since a CCIS stable-call reset may propagate through several offices, combined measurements from several offices tend to overstate the incidence of this type of call failure since each reset may be counted in several offices.

Table VIII gives the rate of stable-call resets. Although the resets may occur on either a CCIS incoming or outgoing attempt, the reset rates shown in Table VIII are expressed only in terms of incoming CCIS attempts to more closely correspond to other IMA failure rates.

V. CONCLUSION

We have explained how IMA data are used to measure switching performance and have demonstrated, through data on 1.6 billion calls collected from 46 study offices, that the SPC network signaling performance for CCIS shows an improvement over conventional signaling. Common-channel interoffice signaling eliminates the possibility of permanent signals or partial dial time-outs by combining seizure and address information in the CCIS initial address message, which can be retransmitted if an error is detected. Common-channel interoffice signaling error checking and retransmission capabilities protect the signaling system from loss of information caused by hits, fades, and noise in the transmission media. These capabilities permit successful switching of 99.95 percent of all CCIS attempts. The largest component of the failures represents incomplete screening at the preceding offices rather than CCIS problems. These capabilities permit CCIS to complete calls that would be lost with conventional signaling and greatly reduce

Table VIII—CCIS call resets (percent)

No. 4 ESS	0.013
No. 4A ETS	0.014
Composite	0.013

the incidence of IMA reports caused by phenomena not related to calls. These are the main reasons that IMA performance for CCIS is better than conventional signaling.

Common-channel interoffice signaling provides the capability for reporting problems to all affected offices through backward failure signals. The combination of a lower number of ineffective attempts and these failure signals allows a more efficient analysis effort.

Concentrating signaling information onto the CCIS network required the network to be highly reliable. The high degree of availability is assured by duplication of signaling links and STPs and automatic response to signaling network failures. Ongoing performance monitoring demonstrates that high reliability has been achieved.

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